"Next-generation Power Management User Interface for Office Equipment"

Focus: End-Use Efficiency; Commercial Buildings

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Project Description

This section includes a Narrative Description *of the need for and content of this project, followed by a discussion of how the project fully meets the* Eligibility and Completeness/ Feasibility Screening*, the* Technical Evaluation Criteria*, and the* Policy Evaluation Criteria.

1. Narrative Description

The goal of this project is to develop and test a set of standards for future power management user interfaces to gain maximum energy savings in office equipment. An improved interface by itself will gain some energy savings, but they will be greatly magnified by having the improved interface standard across all office equipment and ultimately other devices. The standard will not be rigid, but will lay out principles and guidelines that designers can adapt to their specific needs and opportunities. While the main focus of the project is office equipment, we will design the standard with a variety of other types of electronics in mind, so that its ultimate applicability will be as wide as possible. For further background on the details of energy savings from power management and common interfaces, see the section "Power Management Operation and Savings".

Electricity savings from power management of office equipment has been one of energy efficiency's premier success stories. The problem of large amounts of energy being used by office equipment was first recognized only in the late 1980s (Norford et al., 1990). This was followed by assessments of the methods and potential of the efficiency opportunity of power management, technical description of how it could be broadly implemented in products, and establishing effective public policy through the US Environmental Protection Agency's ENERGY STAR program (EEOT, 1992). Less than five years from the initial diagnosis, products were available for sale and in use by consumers saving energy through power management. Beginning with PCs and monitors, the ENERGY STAR program has since grown to include printers, faxes, copiers, scanners, multi-function devices, and recently added primarily home devices such as televisions and videocassette recorders. The program has attained estimated market shares of 90% in monitors, 70% in PCs, and comparably high rates in printers[1], annually saving the nation many TWh of electricity and consumers over a billion dollars (Koomey, Cramer, Piette, and Eto, 1995).

Despite this success, many devices that are capable of power management are not saving energy because the features are disabled, incorrectly configured, or prevented from activating by a hardware or software problem. An LBNL study of computer power management found for ENERGY STAR compliant devices only 11% of PCs and two-thirds of monitors fully power managing (Nordman, Piette, & Kinney, 1996). Copier power management is often disabled by service technicians on installation. A recent study by LBNL of copiers found about 30% of ENERGY STAR copiers fully on at night; power management was disabled on *at least* this fraction of copiers as some of the rest were manually turned off (Nordman, Piette, Kinney, & Pon, 1998). While systematic studies of printers, fax machines, scanners, and multi-function devices (MFDs) have not been made, anecdotal reports indicate that disabling still occurs often enough to be of concern. On many PCs, if

[1] Even some non-compliant computers still have power management capability, but don't power down below the program's 30 *W* standard in low-power mode. Additionally, some models that are compliant are not listed by manufacturers, so that the market effect of the program is greater than what the lists of compliant products suggest.

the precise brand and model of the attached monitor is not specified in a control panel *and* known by the operating system to be ENERGY STAR compliant, power management is prevented and not offered as an option; as the monitor often still works fine, it isn't apparent that there is a problem. Some network systems prevent power management from operating on a PC, but since it usually isn't apparent when a PC is power managing or not, most users aren't be aware of the problem. Many devices have non-optimal power management settings, such as excessive (e.g. 5 hour) delay times or only partial powering down.

Power management controls show little consistency in the terms and symbols used and in the structure of the controls. This is particularly a problem across device types, as between a PC and a copier, but often within a single type of device. Many controls are also confusing or ambiguous. PCs and monitors, for example, may have multiple low-power modes that are activated in succession. It is often unclear if the timers for successive modes operate in parallel—all starting simultaneously—or in series—with one timer started as the previous one finishes. Many devices have an 'on/off' switch for power management in one location and the timer and other configuration variables in another location—a user must know to look in both to correctly check or configure power management. For the user who wants to know if power management is functioning, many devices provide little or no indication of their power management status[2]. This problem is most acute for PCs, which is ironic as they are the most prone to a hardware or software problem defeating power management. It is often impossible for the average user to know if a PC is power managing (other than to hear the disk drive spin down, which is typically independent of other power management).

A great opportunity that electronic circuits provide is the capability of a device to monitor itself and report the results to the user. A device might indicate, for example, how much energy it used in the previous week, how much was saved by power management, and how much it *could* save if power management were enabled. We are aware of only one device that monitors and makes available to the user the actual savings from power management (and this lone example is an external controlling device whose only function is to accomplish power management). Networks provide an excellent opportunity to make it easier to check power management configuration and operation.

Another example of confusion is a recent copier model that has three power management features: "energy-saver", "auto-power off", and a timer function. 'Energy saver' only occurs when a special key is pressed (never automatically) and the control is for the percentage of energy reduction that occurs. 'Auto-off' only occurs automatically, and the control is for the delay from last use. The timer can be used to specify times of the day and week at which the copier automatically turns on or off. The three controls are located in separate menus and don't refer to each other. When auto-off and the weekly timer are both active, the manual does not indicate which takes precedence. No guidance is given on how they relate to each other or what "good practice" is for an overall power management strategy. This device, like many copiers, still uses some energy when "off". Many people assume that "off" means no energy use; either that needs to be widely recognized as not true, or an alternative term for these "mostly off" states needs to be agreed upon. Even the location of physical switches influences energy use; an LBNL study found that monitors with the power switch on the front of the device were more likely to be turned off than those with the switch on the back (and hence more difficult to access).

Interviewing users of products and support personnel provides invaluable information about their attitudes and behavior. Copier technicians often report routine disabling of power management and other energy-saving features to avoid service calls. Many computer support personnel "temporarily" disable power management when diagnosing a problem, then neglect to reenable it, or ascribe problems to power management that have long been fixed. Copier users report the relatively slower speed of duplexing as a reason to avoid using it (duplexing saves energy in paper production), and cite the lack of a "count-down" timer on most copiers as a reason for extra frustration when recovering from low-power or off modes.

The goal of this project is to initiate and support a process that will result in future office equipment and other electronic devices sharing the same basic interface for power management, both in configuration controls and in indicators of status and performance. This will be an improved interface, and so easier to understand and use by itself. However, as a standard across many types of

[2] Ironically, the better the implementation of power management, the less likely a user will be "forced" to be aware of its operation, and so getting positive feedback of its success, or awareness that it is not working correctly.

devices, it will also become familiar and thus additionally easier to use. The International Electrotechnical Commission (IEC) defines a standard as a

> "Document, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context"

The standard will be voluntary—no company will be required to use it—and can be adhered to entirely or only partially. This allows gaining the benefits of standards while retaining flexibility for manufacturers that believe that they have a better approach for one aspect of the interface, or have a product with unique or unanticipated features. An example of an element of such a standard is the common practice of a power-managing monitor changing its indicator light from green (“on”) to amber (“low-power”). This convention could be adopted by all devices with an indicator light. Standard indicators should be used on all devices, whether they have power management features or not.

There are a variety of reasons why the need for such standards will only increase in the coming years. With advances in electronics, their proliferation into devices not traditionally “electronic”, and the trend towards more portability (that requires power management for extending battery life), more and more types of devices will have power management features. As devices become interconnected, interdependent, and smarter, the number of variables affecting power management will only increase, such that controls will likely become more complex and unwieldy. Some future controls will be highly configurable, such as being adaptive to user behavior on a dynamic basis, taking into account network services, informed by detailed daily or weekly calendars, or managing multiple low-power states. This also raises the specter of overcomplexity. With the emergence of OS/2, linux, and Java, the likelihood of multiple operating systems potentially running on a particular piece of hardware has risen. A standard user interface also facilitates the development of network protocols that service or enable power management. The longer we wait to develop a standard approach to power management interface design, the more difficult it will be to gain convergence among a wide diversity of approaches. We still have the opportunity to forge standards when the task is reasonably manageable.

Examples of difficult to use electronic interfaces are many. Video-cassette recorders with blinking “12:00” displays because setting the time is too cumbersome are evidence of a familiar example. Copier controls for imaging are notoriously user unfriendly, with most copiers having advanced features that many users never use and aren’t even aware of. Many copier manufacturers take distinct approaches to controls, with unique terms, symbols, and defaults—sometimes even within the same manufacturer.

Poor interface design can backfire on energy efficiency efforts. For example, a recent study (duPont, 1998) of appliance energy efficiency labels found that only about half of consumers correctly interpret the energy cost and efficiency figure on US Department of Energy labels. The energy use (cost)—a figure to be minimized—is misinterpreted by many as the savings—one that should be maximized—leading to bad decision-making and extra energy use. Some PC power management controls are adjacent to controls that can seriously interfere with proper machine functioning, intimidating many people from changing the power management controls, or cause them to be dismissive of power management if they inadvertently change the wrong control.

Examples of the benefits of standard interfaces are also many and familiar. The standard left/right placement of hot and cold water taps and the standard ordering of automobile foot pedals are cases in which a standard is not only convenient, but also reduces accidents. Electricity plugs *in the U.S.* are another example of a relatively standard interface. Successful standards do not call attention to themselves, and once established, are relatively self-enforcing. Elements of the power management standard should be incorporated into all devices, even those that don’t have power management capability.

One study of terms and symbols on photocopiers found that experienced users preferred pairs of words and symbols rather than symbols alone, and found that symbols used by manufacturers performed poorly compared to alternatives (Chambers et al., 1992). Interestingly, by far the worst recognized symbols were the two relating to power management status, “wait”, and “ready”.

While the main focus of this project is office equipment, the principles and standards will apply to many other types of devices in businesses and residences, resulting in additional energy savings and more satisfied consumers. In addition, we can expect that the success in controls standardization may stimulate a follow-on effort for energy controls for non-electronic devices (e.g. home lighting and HVAC systems) and for non-energy controls such as imaging (e.g. printing and copying), and water use. Better imaging controls could save electricity by reducing the total number of images made, and could save significant energy by reducing the amount of paper produced. Power management in office equipment is a logical first effort in a larger domain.

Energy savings from this project are difficult to assess precisely, but we can indicate their magnitude by examining the effect of raising power management rates from their often low current levels to 100%. This was done in one study (Koomey, Cramer, Piette, and Eto, 1995) and the year 2000 savings from "current" practice—6 TWh/year—could be more than doubled to 16 TWh/year (and the comparable figures for 2010 are 10 and 23 TWh/year). Thus, the potential for increased savings is currently about 10 TWh/year, and rising. While a standard interface would not garner all of this potential, even modest increases in enabling rates have a large impact. Gaining just 10% of the additional potential would annually save the nation over $100 million and the state over $10 million.

This project will build a foundation of relevant knowledge from several sources. Existing systems will be examined for their power management approaches and details. Average users and interface designers will be interviewed to assess their beliefs and reactions to different kinds of power management controls and indicators. The relevant literature will be reviewed to glean key principles that should inform the interface design. The standards and other institutions that could aid in the wide adoption of the interface will be assessed to understand the relevant processes necessary for that to occur. Previous experience with forging interface standards in other domains will be summarized to learn from both successes and failures. We will develop the proposed standard, and refine it based on comments from those in the industry as well as from testing it on typical users. Finally, we will initiate the process to have the standard adopted by national and international standards organizations.

Power Management Savings and Interface Examples

Power Management is the ability of an electronic device to automatically change from a full-on ready state to a low-power or off state, based on activity levels, predetermined timers, or user selection. For some devices, such as PCs, retaining complete operational status on emergence from sleep is vital. For others (PCs, faxes, and printers), reawakening based on electronic signals is required.

The U.S. EPA ENERGY STAR program establishes *maximum power* levels for low-power modes; *performance characteristics* such as maximum recovery times to full operating capability; and *implementation requirements* such as equipment being shipped enabled. These power values are combined with an "operating pattern" to estimate annual electricity use and savings (the operating pattern is the distribution of time across the year in the various operating modes). Table 1 shows the typical power levels and savings achieved by ENERGY STAR equipment, as well as typical annual energy use and savings values. More recent studies have better data on individual devices, but none address the full range of equipment that this study did. The more recent studies show a greater difference between active and low-power modes for PCs, monitors, and copiers, so these savings are conservative.

Table 1: Power Levels and Annual Energy Use (and Savings)

	Power Levels *(W)*		*%*	**Annual Energy Use** *(kWh/year)*		*%*
Device	**Active**	**Low-Power**	***Savings***	**Non-PM***	**ENERGY STAR**	***Savings***
PC	55	25	*55*	200	90	*55*
Monitor	63	14	*78*	170	125	*26*
Laserprinter	80	25	*69*	260	120	*54*
Copier (small)	190	5	*92*	880	590	*33*
Fax	35	15	*57*	260	140	*46*

Source: Koomey et al., 1995. *"Non-PM" is Non-Power-Managed.

When these savings are multiplied by tens of millions of pieces of office equipment, it is clear that many hundreds of millions of dollars worth of electricity savings are at stake.

As we propose an improved, standard interface, it is helpful to examine some examples of existing interfaces.

Figure 1 shows an example of a poor power management interface. It is only accessible on system reboot, making it cumbersome for users and IS managers to simply interrogate as well as to change the configuration. It includes many terms that are non-obvious, non-standard, and not defined. The relation among the various controls is not clear, and no guidance on what appropriate values might be is given. As this is a text-only interface, there are no symbols used to provide clues to the meaning of the controls. Much of the complexity is unnecessary—information that the user would never need is included. Most users find such controls intimidating, and believe (sometimes correctly) that a mistake in changing the configuration will lead to serious problems in their machine operation. It is essential for wider enabling of power management that it "fail softly", by simply not accomplishing energy savings rather than interfering with device performance. This type of computer also has separate controls within the operating system for additional monitor controls, and the two control setups do not refer to each other.

Figure 1. A poor example of a power management interface.

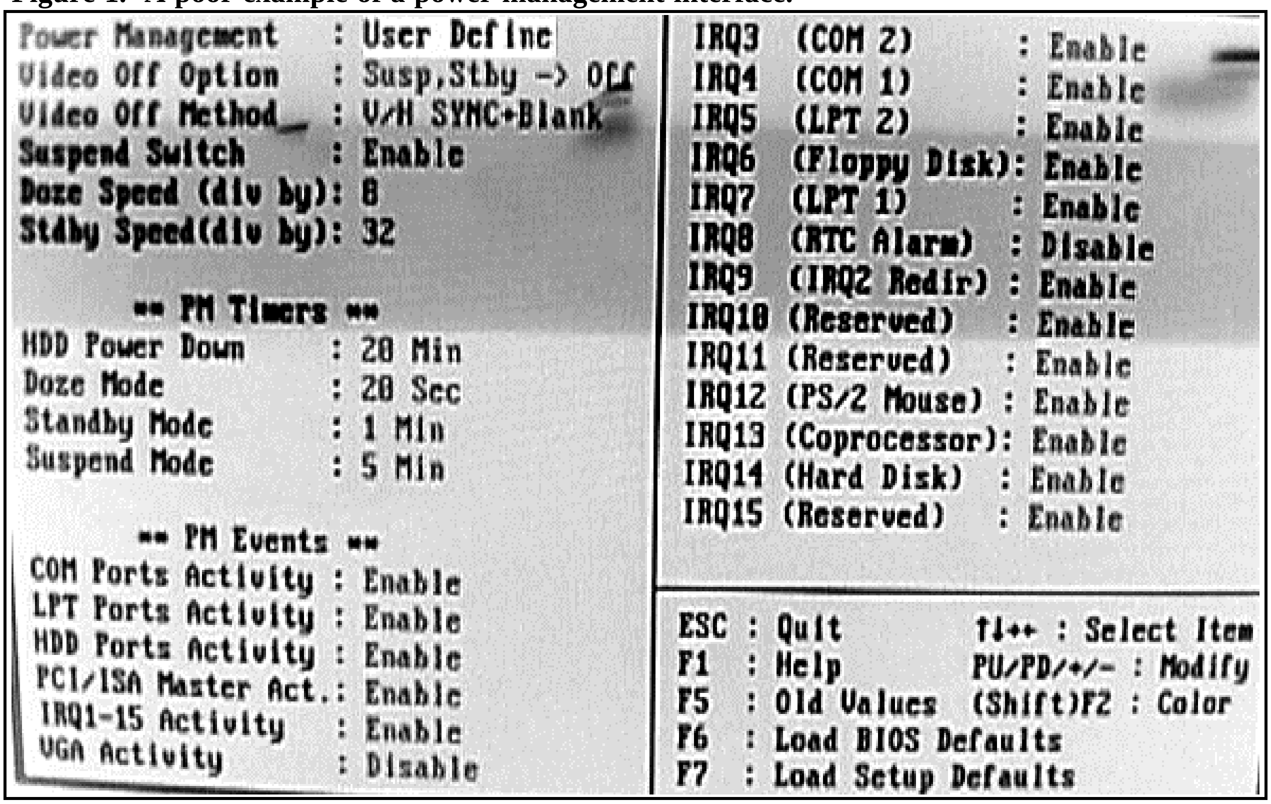


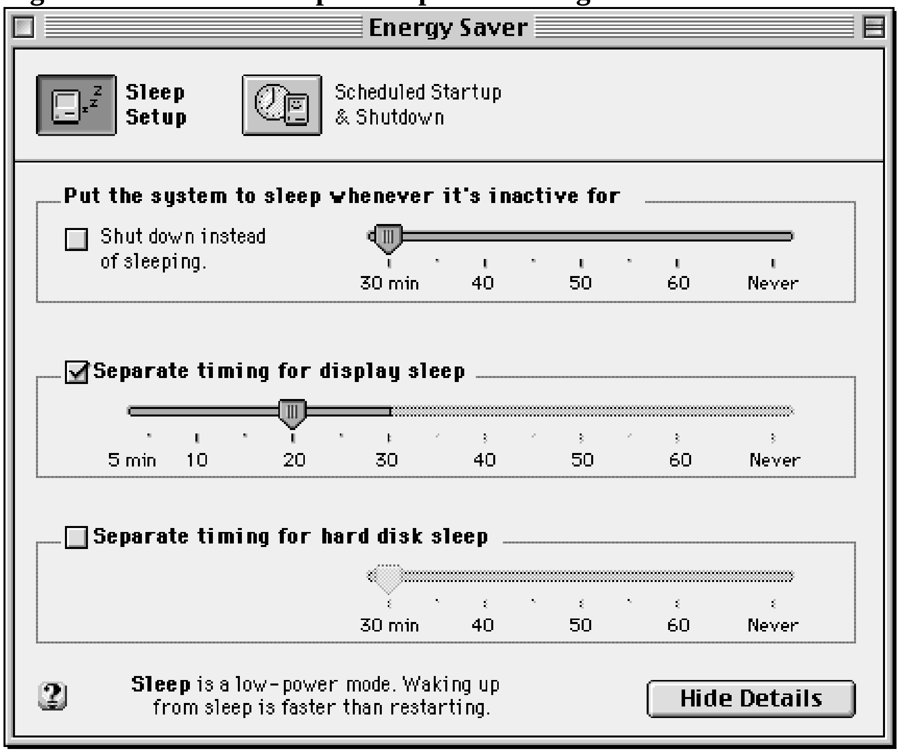
Figure 2 shows a much better example, though this "control panel" for a PC still includes many specific concepts. These include "Sleep" (a low-power state), "Start-up" and "Shutdown"[3] (changes of state), "inactivity", "restarting" "Energy Saver" (the title and purpose/goal). The idea of "inactivity" is an important one, since that determines whether power management happens at all; 'inactivity' isn't defined in the controls, and could reflect keyboard/mouse input, network activity, incoming mail, an incoming fax, or other notions of activity. It is implied that one definition of inactivity applies to all three devices, but this is not conclusive. On many PCs, the hard disk depends only on hard disk activity.

[3] The "Scheduled Startup and Shutdown" icon brings up a separate window for specifying days of the week and times at which those actions should automatically occur.

Two devices are 'slaves' of the PC—the monitor ("display") and the disk. The interface implies that all timers operate in tandem; the graphic nature allows this, while a numeric interface would not. This PC is in fact *not* ENERGY STAR compliant, as its low-power mode does not reach the 30 W standard. However, it does have power management controls, and it controls the monitor which *is* ENERGY STAR compliant.

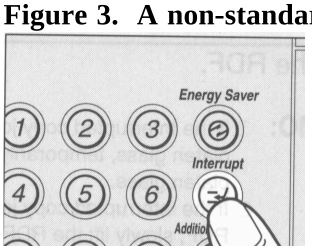
Some useful information is presented at the bottom of the screen, with a little more available through the “question-mark” icon. No guidance is given on what appropriate settings might be or what the benefits of power management are. Two special icons are used, the general power management indicator and the scheduled startup/shutdown page.

Figure 2. A better example of a power management interface.



A final aspect of power management interfaces is the use of terms and symbols to communicate concepts. Figure 3 shows the “Energy Saver” symbol used on one brand of copier. The symbol is not standard or particularly informative about what energy saving is. For a symbol to have much meaning to the ordinary user, it will have to be used on many or all devices to be seen often enough to make an impression. This copier flashes red under the ‘energy saver’ symbol; some PCs flash green when power managing; and monitors usually have a constant amber indicator to mean the same thing. Consistency in color and action would help consumers quickly and correctly recognize different power states.

Figure 3. A non-standard power management symbol.



This project will thoroughly and rigorously catalog the terms, symbols, and approaches used in power management controls. This discussion is intended to give just a flavor of that and show some of the major flaws in current implementations.